Continental Shelf Embayments of the Eastern Margin of the Philippines; Lamon Bay Stratification & Circulation

Arnold L. Gordon
Lamont-Doherty Earth Observatory
61 Route 9W
Palisades, NY 10964-8000
tele: (845) 365-8325
fax: (845) 365-8157
agordon@ldeo.columbia.edu

Award Number: N00014-10-1-0426

LONG-TERM GOALS

To investigate the circulation, stratification and the Shelf-Slope interaction, and the resultant ocean productivity, within a major embayment, Lamon Bay, of the eastern margin of the Philippines.

OBJECTIVES

The research objectives of the Lamon Bay program is to quantity the spatial and temporal characteristics of the ocean processes governing the stratification & circulation within Lamon Bay and their relationship to regional marine productivity and ecosystems and to investigate possible linkage of Lamon Bay dynamics to the larger scale, such as the development of the Kuroshio. The Lamon Bay program contributes to the OKMC

APPROACH

The Lamon Bay observational program of 2011-12 consisted of a two ship based programs [figure 1a,b; 2] connected with a mooring array time-series, Table I; as well as a land based high frequency radio array (Pierre Flament activity), and satellite coverage of SST, ocean color and altimetry. The Lamon Bay research into the Kuroshio before reaching the Luzon Strait contributes to the larger regional scale OKMC program. This program represents collaboration with Cesar Villanoy and colleagues of Marine Science Institution in the Philippines.

WORK COMPLETED

The Lamon Bay program provides significant insights into the workings of the embayment environment of the eastern coast of Luzon, the Philippines. Reports of Lamon Bay cruise 1 (LB01, May/June 2011) and Lamon Bay cruise 2 (LB02, April/May 2012) provide an overview of the observations and basic insights to Lamon Bay oceanography and its place in the larger scale regional ocean. The reports are available at:

Lamon Bay 1 Report: http://www.ldeo.columbia.edu/~agordon/Reports/LamonBay2011_Report.pdf

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Continental Shelf Embayments of the Eastern Margin of the Philippines; Lamon Bay Stratification & Circulation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Lamont-Doherty Earth Observatory,61 Route 9W,Palisades,NY,10964-8000**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**11**	

Lamon Bay 2 Report: http://www.ldeo.columbia.edu/~agordon/Reports/LamonBay2_rept.pdf

The research objectives of the 2011-2012 Lamon Bay observational program was to quantity the spatial and temporal characteristics of the ocean processes governing the stratification & circulation within Lamon Bay and their relationship to marine productivity and ecosystems and to investigate possible linkage of Lamon Bay dynamics to the development of the Kuroshio.

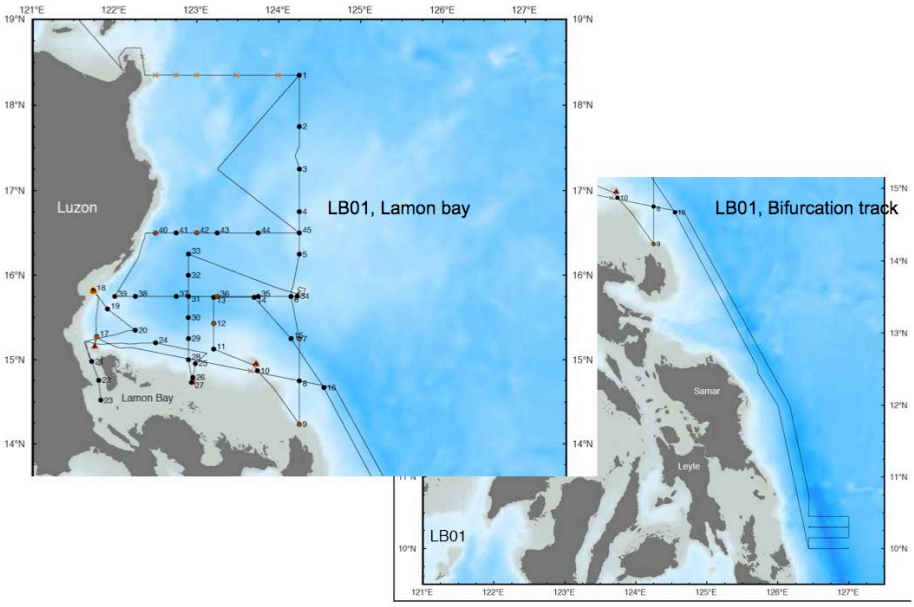

Figure 1a. Station/track map of Lamon Bay 1, May/June 2011. Red dots show drifter deployments [13 in total]; red triangles are mooring deployment sites [see Table I for data return]. There were 45 CTD stations most with water samples for chemistry. The track extending the coverage to the NEC bifurcation during Typhoon Songda

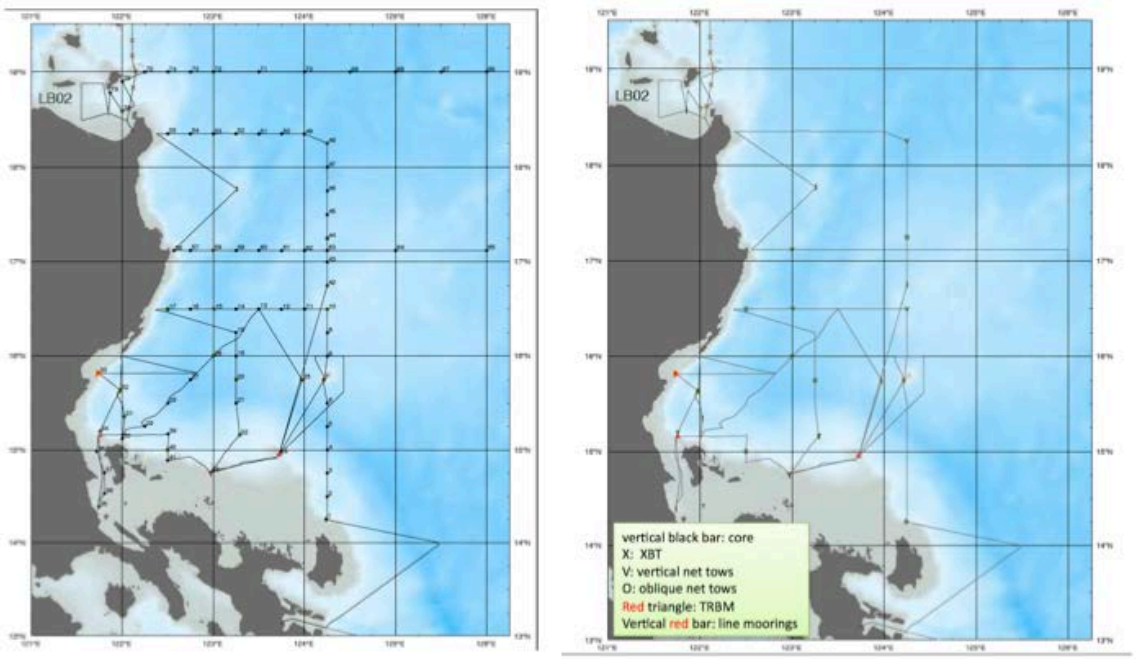

Figure 1b [left panel]: Station/track map of Lamon Bay 2, April/May 2012. There were 78 CTD stations (temperature, salinity, oxygen), to 1500 m or to the shallower sea floor; 4 stations descended to 4000 meters to observe the waters within a deep ocean trough within Lamon Bay. Water samples were taken for CTD oxygen standardization and for determination of nutrient, carbon chemistry, and ecosystem parameters. Underway data, besides ADCP and Revelle 'Real-time Underway and Meteorological Data' (ocean surface temperature and salinity; oxygen; Chlorophyll-A (fluorometer); Transmissivity), included pCO_2.
[right panel]. A subset of stations had net tows to ~200 m to sample the 'living' component (plankton, and the occasional fish) of the upper water column. Gravity cores of the sea floor sediments were taken at 9 sites.

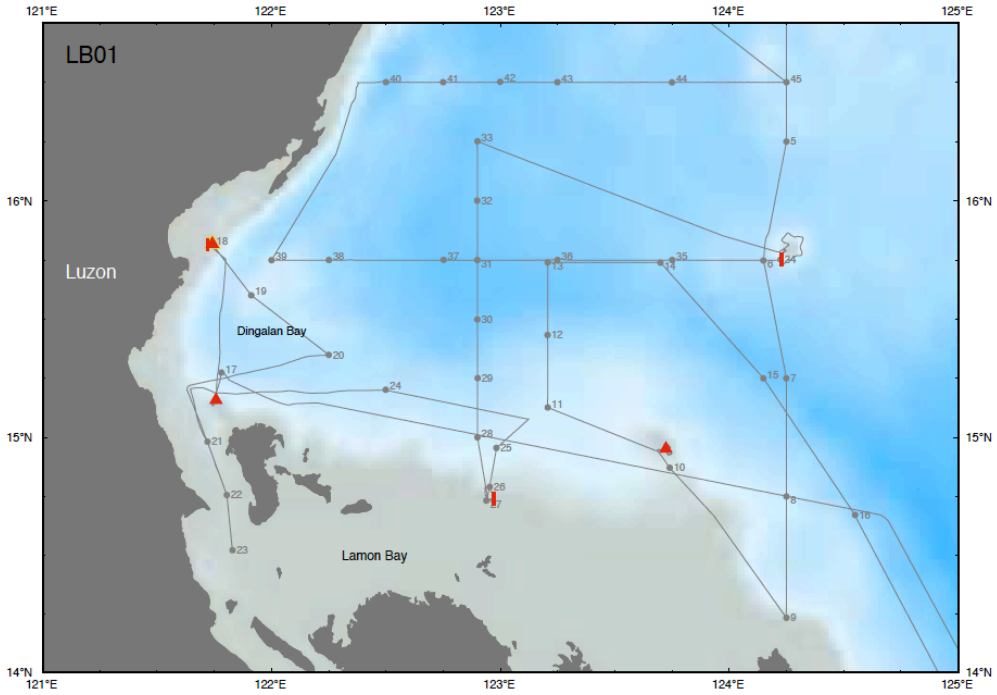

Figure 2: CTD station distribution within Lamon Bay proper (Phase 2 and 3, see figure 1). red triangles = TRBM (trawl-resistant bottom mount); red bars: T/S moorings with cable]

TABLE Ia Moorings deployed during Lamon Bay cruise 1 [May/June 2011]

what	long°E	latitude°N	Day GMT	depth
TRBM1	123.7233	14.9517	22may2011	145
TRBM2	121.7572	15.1581	27may2011	192
TRBM3:	121.7415	15.8186	28may2011	180
T/S Bottom:	121.7201	15.8158	28may2011	86
Mooring [line] 1	122.9715	14.7405	30may2011	226
Mooring [line] 2	124.2274	15.7540	31may2011	757

TABLE Ib Moorings recovery results in 2012 Lamon Bay cruise 2 [April/May 2012]

Mooring	recovered [local]	data recovery
TRBM1	dragged for; did not leave sea floor; did not recover	
TRBM2	dragged for; ascent to 30 m below sea surface; did not recover	
TRBM3 [with seacat]:	4/30/12 15:00	full data
T/S Bottom:	4/30/12 16:30	recovered;
Mooring [line] 1	5/3/12 7:15	full data; deep S4 cm flooded
Mooring [line] 2	5/4/12 6:00	full data

RESULTS

The Lamon Bay 2011 cruise results are discussed in last year's annual report. Here I'll focus on the differences between the 2011 cruise (LB01) and the 2012 cruise (LB02), and ENSO. The 2012 conditions within Lamon Bay reveal a greater presence of North Equatorial current water (NEC), relative to the 2011 stratification [figure 3]. which was dominated by western North Pacific subtropical water, of the Kuroshio recircualtion gyre.

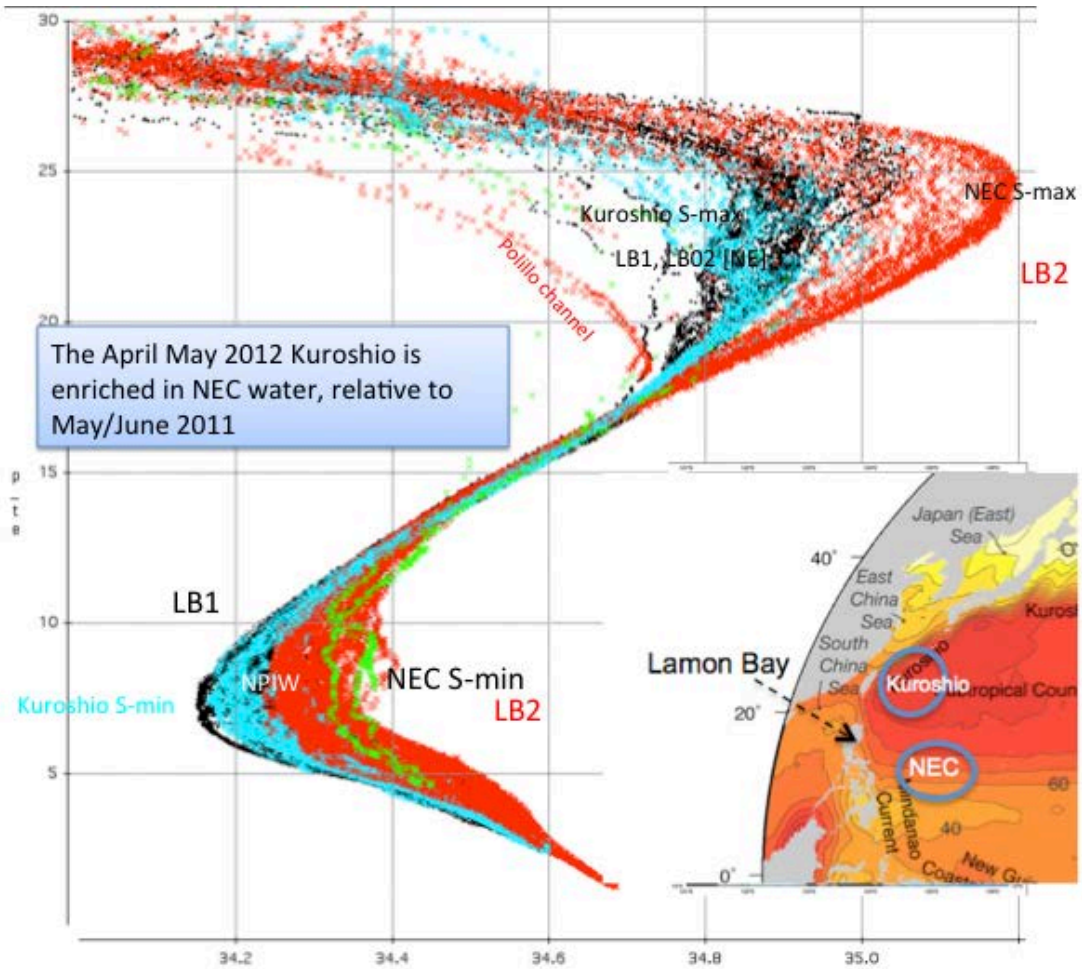

Figure 3 LB02 thermohaline pattern (red) in Lamon Bay reflects dominance of North Equatorial Current (NEC) water; whereas LB01 (black) reflects Kuroshio recirculation gyre regime. The cyan LB02 stations, displaying Kuroshio T/S, are in the northeastern part of the station array. The LB02 green stations are within the embayment of Port Irene.

In addition to a greater intrusion of NEC water, the Kuroshio within Lamon Bay is much stronger in 2012 [figure 4] .

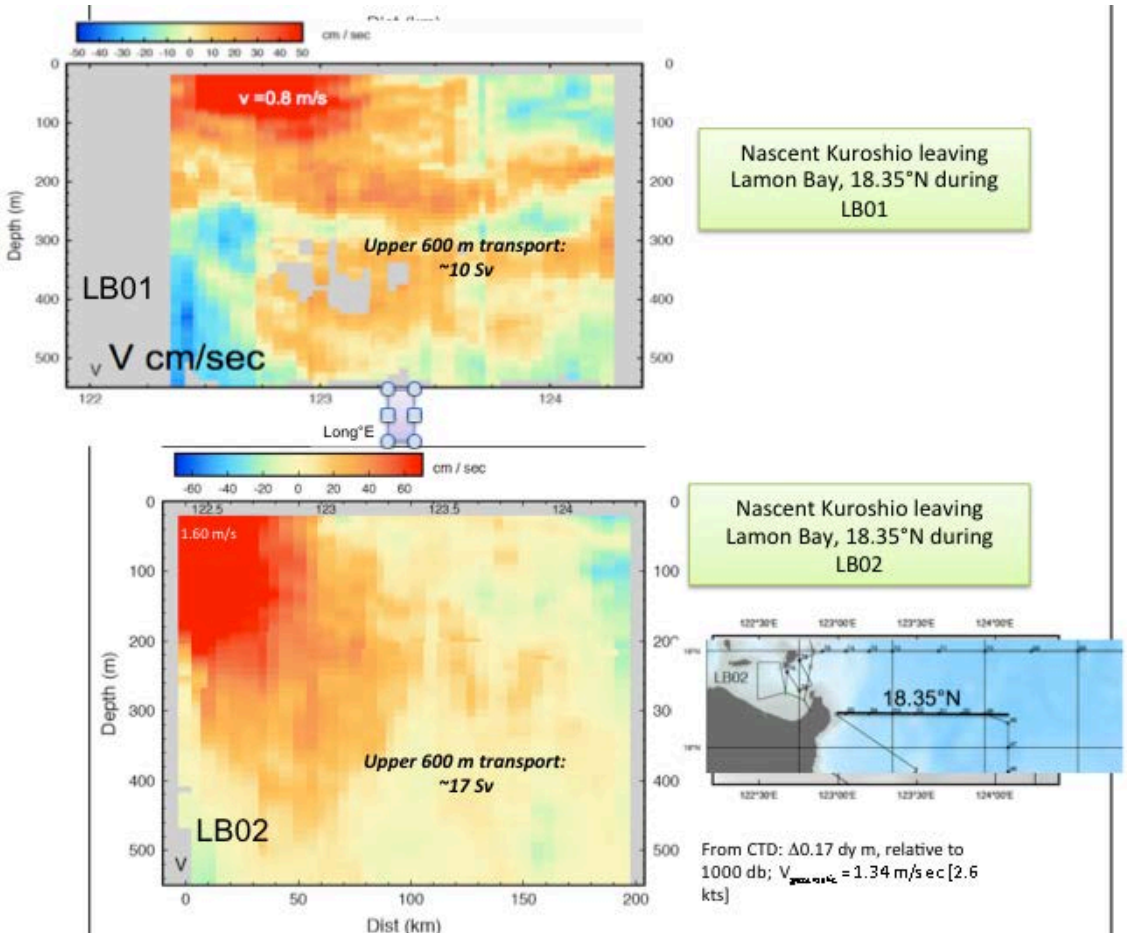

Figure 4. Crossing 18.35°N the Kuroshio immediately before reaching Luzon Strait, is 70% stronger in 2012 than in 2011. Data from R/V Revelle hull mounted ADCP.

The hull ADCP and the CTD thermohaline stratification reveal a shift in circulation pattern between 2011 and 2012 Lamon Bay cruises [figure 5]. In 2012 the Kuroshio is enriched in NEC water, and the subtropical water presence of the Kuroshio recirculation cell has retreated northward.

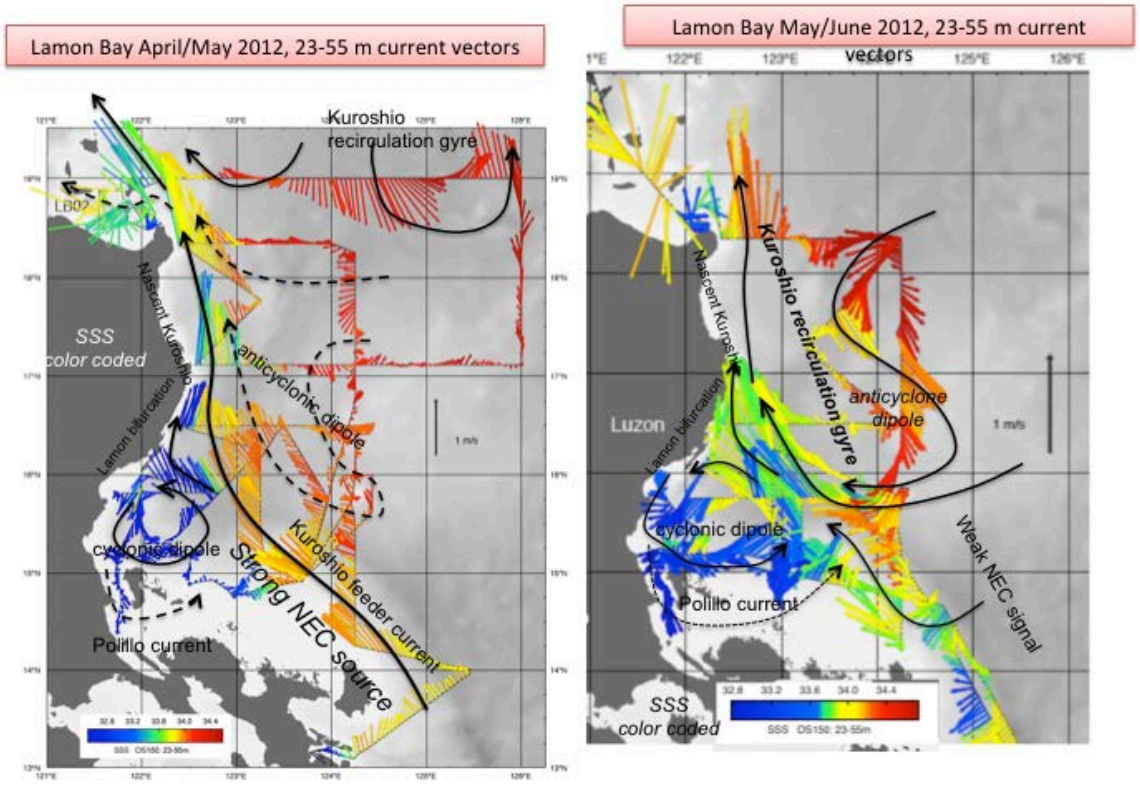

Figure 5. Solid arrows denote stronger flow, with clear T/S source water signal. LB02 Kuroshio recirculation gyre retreats northward to be replaced by NEC waters; LB01 shows southward penetration of the Kuroshio recirculation gyre, with reduced NEC water [vectors not to same scale]

The time series offered by the Mooring at 124.23°E, 15.75°N [table 1] reveals the timing of the shift from the Lamon Bay 2011 cruise condition to that of the Lamon Bay 2012 condition [figure 6]: the intrusion of salty upper thermocline NEC occurred in December 2011. The moorings in the SW corner of Lamon Bay, within the cyclonic circulation cell (see figure 5), find the salty thermocline water arrived there ~ 2weeks after the mooring time series shown in figure 6.

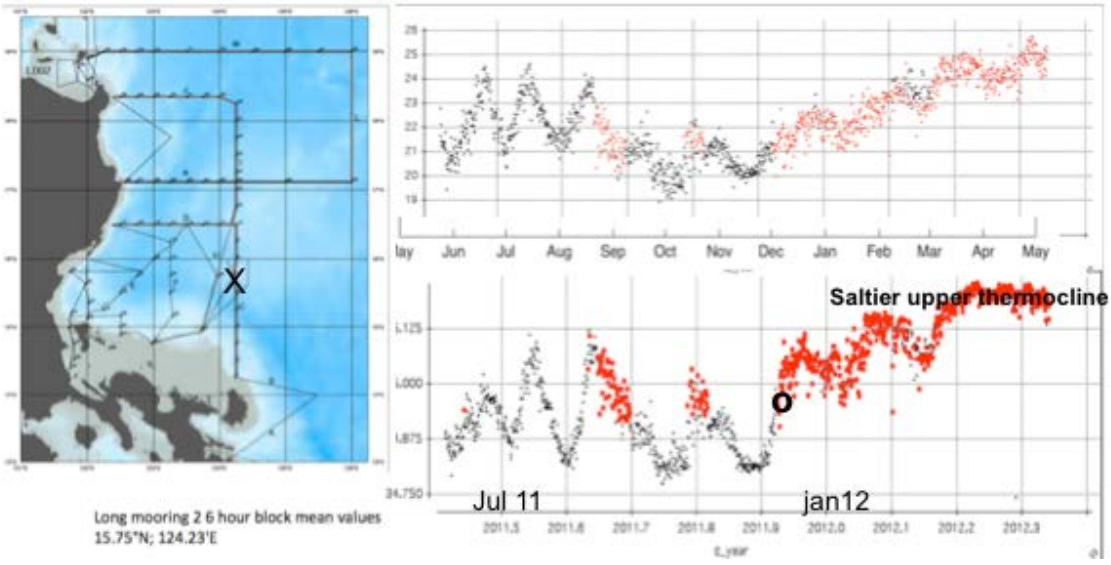

Figure 6. The transition to a saltier upper thermocline introduced by the NEC water, occurred in December 2011 [the o marker] , at peak of La Niña phase

The NEC Bifurcation is further north during El Niño *[longer term trend to more southern position]*

The cause of the 2011 to 2012 shift in the Lamon Bay Kuroshio composition and transport is suspected to be ENSO based, naming the relationship of the NEC Bifurcation with ENSO: NEC Bifurcation further south in the 3 months before LB02 than in the 6 months before LB01, resulting in increased NEC injection into the Nascent (Lamon Bay) Kuroshio [fig 7]

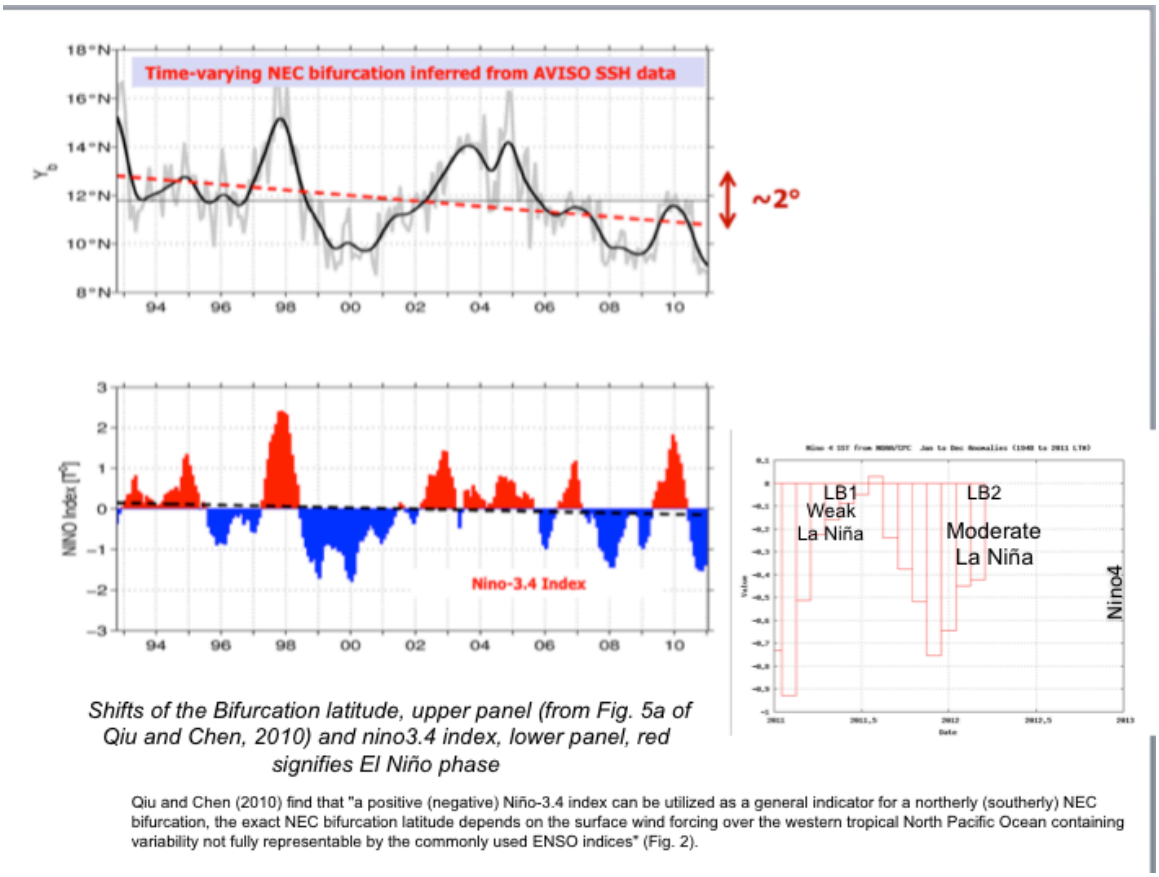

Figure 7. The NEC bifurcation latitude (Qu and Chen, 2010), and in right panel the relationship of the two Lamon Bay cruises to the ENSO index, N4. NEC Bifurcation further south in the 3 months before LB02 than in the 6 months before LB01, resulting in increased NEC injection into the Nascent (Lamon Bay) Kuroshio.

The NEC Bifurcation feeds tropical Pacific water into a network of pathways to far away destinations; the temporal variability in routing couples ENSO to the larger scale ocean and climate systems (Figure 8).

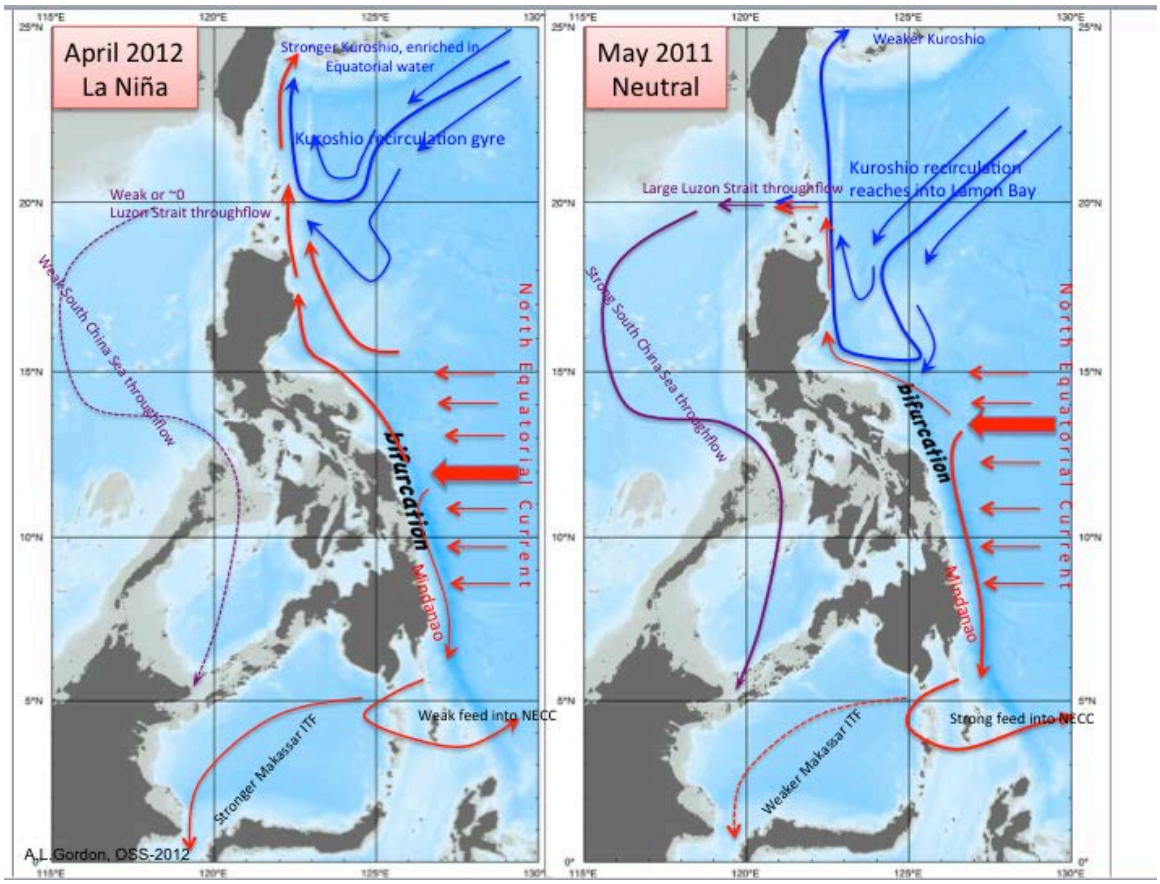

Figure 8. This schematic is based on the CTD (T/S stratification) and ship-based ADCP currents of the upper ~600 m obtained by the Lamon Bay research cruises of May/June 2011 and April/May 2012, which covered the area south of ~19°N west of ~126°E and the NEC bifurcation region [typhoon detour in 2011 and transit from Fremantle in 2012]. The nino4 in May 2011 was near zero, but we take it as representative of an El Niño condition relative to the La Niña condition of April 2012. The South China Sea throughflow connection is from Gordon et al, 2012, GRL; Luzon Strait throughflow and ENSO from Hurlburt, et al., 2011, Oceanography.

A summary of the NEC Bifurcations as one of the key switches in the world ocean:

- During La Niña there is increased injection of NEC tropical Pacific water into the Kuroshio, coupled to reduce flow into the SCS via Luzon Strait. In this way during La Niña there is increased transfer of tropical Pacific water into the subtropical North Pacific;
- During El Niño the subtropical North Pacific is more 'isolated' from the tropical Pacific water; the Kuroshio recirculation cell reaches southward into Lamon Bay as the Nascent Kuroshio weakens; there is increased Luzon Strait ‘leakage’ into the South China Sea;
- Reduced SCS throughflow during La Niña alters the Makassar Strait throughflow profile making for warmer, stronger ITF;
- More: effect on the WPWP; on marine ecosystems, linkage with PDO.

Analysis of the Lamon Bay data, in collaboration with Pierre Flament and Philippine colleagues is directed at these objectives:

- Circulation & stratification and physical processes within Lamon Bay;
- Linking the physical processes to the marine ecosystems of Lamon Bay;
- Relating Lamon Bay oceanography to the larger regional scale, including the relationship to the NEC Bifurcation and Kuroshio generation and characteristics of the flow into Luzon Strait.

IMPACT/APPLICATIONS

The spatial and temporal shelf/slope interactions processes within and at the boundaries of Lamon Bay may be instrumental in the origin and dynamics of the Kuroshio Current including the links of the Kuroshio to the North Pacific subtropical gyre and Pacific North Equatorial Current Bifurcation. The Lamon Bay dipole circulation pattern is likely closely linked to the active marine ecosystem characteristic of Lamon Bay.

TRANSITIONS

None

RELATED PROJECTS

OKMC (Origin of the Kuroshio and Mindanao Current)

REFERENCES

PUBLICATIONS

PATENTS

None